regime in the subarea.

The construction of dams and implementation of flood-control practices, channelization, increased water diversions, and displacement of native cottonwood and willow with tamarisk (salt cedar) have resulted in the Rio Grande becoming seasonally intermittent between Fort Quitman, about 70 miles southeast of El Paso/Ciudad Juarez, and Presidio. On the Rio Grande upstream from the subarea, Elephant Butte and Caballo Reservoirs (in southern New Mexico), impound and release virtually all Rio Grande flows for urban, industrial, and agricultural uses in the El Paso/Ciudad Juarez region. Existing water rights, international treaties, and operational policies administered by the Rio Grande Compact Commission limit Rio Grande flow from this region. The limited return flows to the Rio Grande from these uses have significantly degraded water quality. Those return flows are significantly reduced between Fort Quitman and Presidio as they pass through a reach overgrown with tamarisk and are evapotranspired. This often results in little or no surface flow from the Rio Grande entering the subarea from above the Rio Conchos.

Water-quantity, water-quality, and aquatic-biological characteristics within the subarea are heavily influenced by the Rio Conchos (Davis, 1980). In the Rio Conchos watershed, upstream from the subarea, expanding agricultural, mining, and timber harvesting activities as well as urban and industrial development affect both the quantity and quality of Rio Grande flows through the subarea. The Pecos and Devils Rivers are tributaries to subarea 6 at Amistad Reservoir. The natural discharge of saline ground water into the Pecos River in New Mexico also affects the water quality of Amistad Reservoir (Schertz and others, 1994).

Water Quantity

The availability of streamflows sufficient in variability, magnitude, and duration to protect natural resources that are dependent on these flows is the most serious water-quantity issue in this subarea. If sufficient streamflow is not available to fully support and satisfy all competing water needs, the issue of water quality becomes academic. Prior to 1915, the Rio Grande flowed unimpeded through relatively undisturbed lands in the sparsely populated subarea. At Presidio/Ojinaga, a dramatic change in the river is visible due to the dominating influence of inflow from the Rio Conchos. The Rio Conchos typically supplies the largest percentage of Rio Grande flows allocated by Mexico in accordance with the 1944 Treaty between the U.S. and Mexico. The total annual flow of the Rio Conchos averaged 737,000 acre-feet through the 1980's, more than five times the flow of the Rio Grande measured just above its confluence with the Rio Conchos (International Boundary and Water Commission, 1989). Also, the flood-peak histories of the Rio Grande and Rio Conchos are dramatically different, even though both rivers are heavily regulated.

Dams on the Rio Conchos are operated primarily for water storage. Consequently, the Rio Conchos sometimes experiences high peak flows--71,300 cubic feet per second (cfs) in 1978 and 45,900 cfs in 1991 (Collier and others, 1996). As flood control becomes an issue in the developing Rio Conchos watershed, changes in the annual volume and peak levels of streamflow entering the Rio Grande could affect the long-term maintenance of existing aquatic and riparian habitats and further affect the variability of the flow regime downstream.

Figure 3. Rafting on the Rio Grande near the mouth of Boquillas Canyon, Big Bend National Park (photo courtesy of NPS).

Flow from the Pecos and Devils Rivers' watersheds directly enters Amistad Reservoir (fig. 4). The Rio Grande, which was impounded at Amistad Dam in 1969, has a drainage area of 123,142 mi^2 at the International Boundary and Water Commission (IBWC) streamflow gage located 2.2 miles downstream from the dam. Relative contributions of flow to the reservoir for the period 1968-93 are as follows: the Rio Grande above the Pecos River, about 66 percent (1,836 cfs), the Pecos River, about 11 percent (298 cfs), and the Devils River, about 23 percent (656 cfs), (R.M. Slade, U.S. Geological Survey, written commun., 1997). Mean annual flow from Amistad Reservoir is 2,454 cfs. Although the Devils River watershed is only about 12 percent of the size of the Pecos River watershed, its mean annual flow is more than twice that of the Pecos. Reasons for significant differences in water yields (cfs/mi^2) from the two watersheds are: (1) the Pecos River watershed is mostly arid, whereas the Devils River watershed is mostly semiarid; (2) along much of its length, the Pecos River contains alluvial deposits which allow recharge to ground-water by seepage from the river, whereas the Devils River lies almost entirely within incised limestone canyons, resulting in less ground-water recharge; (3) spring discharge accounts for a higher baseflow for the Devils River, and water diversions for irrigation are greater along the Pecos River.

Ground water is a source of baseflow for streams in the subarea, and its interaction with surface water accounts for differences in water yields between watersheds. The Edwards-Trinity aquifer system (fig. 5) is the principal source of water for domestic, livestock, and public supply east of Big Bend National Park. Although surface water is fully developed, use of water from the Edwards-Trinity aquifer system for irrigation over the